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Moving past the 'Neolithic problem': The development and interaction of subsistence systems across northern Sahul

S. Anna Florin*, Xavier Carah

School of Social Science, The University of Queensland, St Lucia, QLD, 4072, Australia

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ABSTRACT

The 'Neolithic problem' refers to forager/farmer interaction in northern Australia, where despite a shared environmental inheritance with their New Guinea neighbours, Indigenous Australians seemingly rejected both the domesticates and the practices of the Melanesian horticultural economy (White, 1971). This ethnographic example is often used to suggest that hunter-gatherers elsewhere may have chosen not to adopt agriculture. However, the premise of the 'Neolithic problem' has been criticised for its over-reliance on the ethnographic record and on an anachronistic notion of cultural evolution, which exaggerates the dichotomy between New Guinean agriculturalists and Australian hunter-gatherers. In this paper we review the historical and theoretical treatment of the 'Neolithic problem' and the archaeological evidence for subsistence practices in northern Sahul spanning the past 50–60,000 years. Using niche construction theory (Rowley-Conwy and Layton, 2011) to re-examine the archaeological and ethnohistoric record, it is possible to observe the development and expansion of a variety of subsistence systems. Contrary to the premise of the 'Neolithic problem', the past 50–60,000 years of occupation in Sahul has seen the development of a varied array of food-producing subsistence practices in both New Guinea and Australia. However, the archaeological evidence for the expansion of horticultural practices and cultivars outside of highland New Guinea suggests a spatially and temporally narrow window for the adoption of agriculture by Indigenous populations in Cape York. Instead, the interaction between different subsistence systems in northern Sahul may have centred on the New Guinea lowlands and the Bismarck Archipelago, where, in the late Holocene, local communities interacted with other Melanesian and Austronesian populations. Whilst further archaeological investigation is required, it is clear that the image of culturally-static Indigenous Australian populations often implied in the consideration of forager/farmer interactions belongs to another era of archaeological thought.

1. Introduction

> "Many recent hunter-gatherers in rich potential farmlands were in contact with farmers, were not encapsulated, yet never showed the slightest interest in adopting agriculture. These include the peoples of California and the Northwest Coast, and of course much of northern Australia … Such examples, of course, make us wonder just how frequently hunter-gatherers would have adopted agriculture in the deeper past," (Bellwood, 2001, pp.192).

Do hunter-gatherers choose to adopt agriculture? Perhaps the most well-known ethnographic example implying otherwise is that of northern Australia, where Indigenous populations, despite a shared environmental inheritance with their New Guinea neighbours, seemingly rejected both the domesticates and the practices of the Melanesian horticultural economy. The 'Neolithic problem', as it was termed by White (1971), the apparent aversion of Indigenous Australians to the adoption of agriculture, has generated speculation since its European 'discovery'. However, with the incorporation of this ethnographic observation into the realm of archaeological research in the 1970s, the premise upon which it is based has been called into question (Harris, 1977, 1995; Lourandos, 1980, 1983; Gosden and Head, 1999; Denham et al., 2009b, 2009c; White, 2011). Attacked on theoretical and archaeological grounds, the once clear dichotomy between Australian hunter-gatherer and New Guinea agriculturalist has been eroded. If Australasian

* Corresponding author.
E-mail addresses: stephanie.florin@uqconnect.edu.au (S.A. Florin), xavier.carah@uqconnect.edu.au (X. Carah).

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archaeology is to provide an accurate representation of interaction between different populations and subsistence systems in this region, it is time to move past the 'Neolithic problem' and examine the 50–60,000-year record of human-environment interaction afresh.

In this paper we review the historical and theoretical treatment of the 'Neolithic problem', as well as the archaeological evidence for 50–60,000 years of subsistence practices in northern Sahul (see Fig. 1; Clarkson et al., 2015). We propose a new framework, using niche construction theory (Rowley-Conwy and Layton, 2011) to consider this record, and re-examine the development, expansion and interaction of subsistence practices evident in this region.

2. The 'Neolithic problem' and its revision

For Australia's European colonisers, the apparent rejection of agriculture by its Indigenous populations suggested the rejection of 'progress'. Agriculture, characterised by the eighteenth century theory of unilinear cultural evolution, was considered the first step towards Western civilisation, undeniably allowing a better way of life. As Moresby (pp.18) wrote in 1876, "it is strange that these people … remain content to wander about, living precariously … whilst their Papuan neighbours in the near Torres Strait islands build good huts, supply themselves with constant vegetable food and have fine canoes for fishing." The population of Australia was argued to be culturally-static and was classified in comparison to its agricultural neighbours and observers as hunter-gatherer: pre-domestication, pre-sedentism and pre-civilisation (Hiatt, 1996).

In 1971, White's description of the 'Neolithic problem' contested the perception of the Australian Neolithic-revolution-that-wasn't by suggesting Indigenous Australians had chosen not to adopt agriculture. White argued that the Indigenous Australian rejection of agriculture occurred not because of a purported inferiority, but because agriculture was not necessarily advantageous. He, therefore, suggested a primary economic barrier to agriculture: Indigenous Australians were simply "too well-off … to bother" with the horticultural practices of New Guinea (White, 1971, pp.184). To this he added secondary social and ecological barriers: the supposed conservative nature of the totemic religion of Indigenous Australians, and the literal barrier of the Arafura Sea, respectively. Whilst White redefined the role of Indigenous Australian populations within the 'Neolithic problem', his acceptance of Moresby's observation framed his perception of subsistence practices in Sahul: New Guinea populations seen as forming "an (expansive) agricultural frontier", resisted by northern Australian hunter-gatherers (Harris, 1995, pp.852).

Since White's redefinition of the 'Neolithic problem', its premise – the existence of an expansive agricultural/hunter-gatherer frontier in the Torres Strait – has been the subject of critique, focusing on two interrelated elements. First, that the interpretation of the subsistence practices underlying this premise has been over-reliant on the ethnohistoric record, allowing present patterns of subsistence to dominate interpretation of past practices (Harris, 1995; Denham et al., 2009b, 2009c). Second, that the interpretation of the ethnohistoric record, itself, has relied too heavily on an anachronistic notion of cultural evolution, exaggerating the dichotomy between New Guinea agriculturalists and Australian hunter-gatherers (Harris, 1977; Lourandos, 1980; Gosden and Head, 1999).

This second critique has stimulated a series of publications since the early 1980s, which have, by focusing on the complexities and categorisation of Indigenous Australian subsistence practices, highlighted the similarities between New Guinea and Australia. This process has led to the successive redefinition of Indigenous Australian populations as socially and economically complex hunter-gatherers (Lourandos, 1980, 1997, 1983; Williams, 1987), hunter-gatherers practicing agronomy (Yen, 1989), and even proto-agriculturalists and agriculturalists (Gerritsen, 2008; Gammage, 2011; Pascoe, 2014). Heavily focused on the reinterpretation of the Australian ethnohistoric record, these alternative interpretations of subsistence practices in Sahul have both fueled the former critique and remained within the framework they sought to overcome. Even with the extreme reclassification of Indigenous Australian populations as agriculturalists the 'Neolithic problem' has remained. New Guinea and Australia have been interpreted as separate entities, the latter not adopting the still-divergent subsistence practices of the former. As Harris (1995, pp.69) so succinctly stated, "to redefine the problem is not however to define it away."

In 2011, White (pp.90), revisiting his seminal work, wrote that

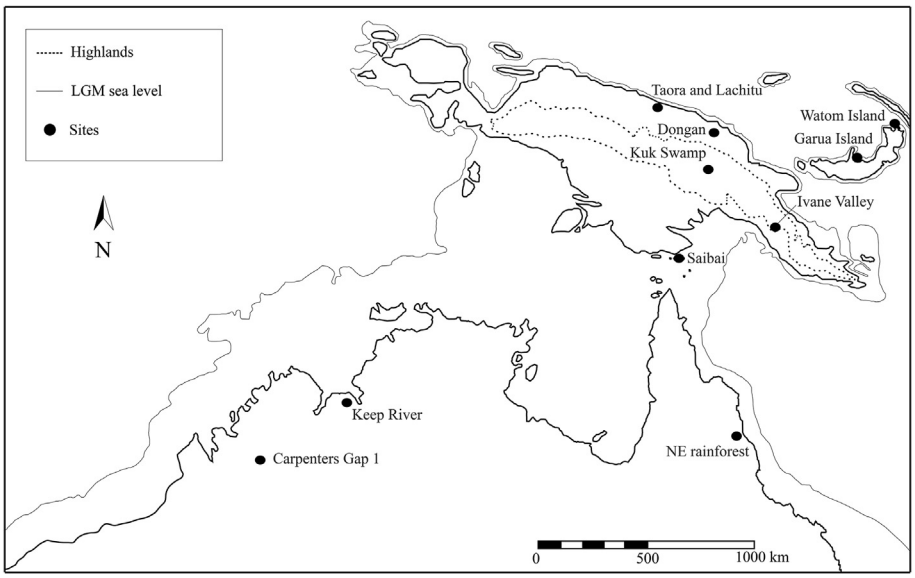

Fig. 1. Map of study area, displaying key archaeological sites mentioned in-text. Base map is redrawn from van der Kaars (1991, Fig. 20). Sea-level at Last Glacial Maximum (18,000 BP). Drawn by X. Carah.

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the 'Neolithic problem' exists "primarily in our minds." His critique reevaluated the subsistence practices of New Guinea, as well as Australia, to suggest that the archaeology of this region is constructed both by the preconceptions of the colonial era and by the contemporary archaeological theory employed to frame research into subsistence practices in Sahul. The term 'agriculturalist' was, in his opinion, no more adequate to describe New Guinea than the term 'hunter-gatherer' was to describe Australia. Instead he suggested the narrowing of research focus to the level of "specific environments and specific subsistence practices," and the rejection of "the hierarchical ordering of groups into hunter-gatherers, small-scale food producers and agriculturalists."

3. Hunter-gatherers, agriculturalists and niche construction

The term 'hunter-gatherer' originated in 1914, the British sociologists Hobhouse et al. (1914b, pp.332) coining it in order to describe the simplest form of human society. Tasked with the explanation of the evolution of 'civilisation', Hobhouse et al. (1914a, pp.209) defined progress as the increase of man's control over nature, "from the lowest known *Naturmenschen* [nature people] to … civilisation." Whilst the terms, hunter-gatherer and agriculturalist, have been defined many times over, this notion of 'progress', shaped by the previous four centuries of European history, still affects both the perception of Indigenous Australians and the theoretical frameworks used to examine the origins of agriculture.

With the establishment of colonial empires in the sixteenth and seventeenth century, Enlightenment philosophers, newly aware of and newly wealthy from other seemingly 'primitive' cultures, reconceptualised human history as a story of progress towards the development of Western civilisation (Wylie, 1985, pp.65–66; Trigger, 2006, pp.166). This narrative of social change, termed unilinear cultural evolution, suggested that societies had a predetermined trajectory, advancing through stages of development from the 'primitive' form towards civilisation (Wylie, 1985, pp.66). Following the publication of 'The Origin of the Species' in 1859, Lubbock (1865, 1870) and other social theorists incorporated the mechanism of natural selection into the theory of unilinear cultural evolution to suggest that the apparent cultural inertia of the more 'primitive' societies was a direct result of their biological inferiority. This implied a scientific explanation and moral absolution for both the seemingly inevitable preeminence of Western civilisation and the simultaneous decline of Indigenous cultures (Trigger, 2006, pp.175–176).

This model of cultural evolution was particularly welcomed by many nineteenth century archaeologists. Through ethnographic analogy, it offered a method of interpreting the seemingly-foreign artefacts of European archaeology, which they only recently understood to have originated from a prehistoric time-depth, through a less 'Eurocentric' perspective (Wylie, 1985, pp.65; Hiscock, 2008, pp.2). Indigenous Australians, divided into Tasmanians and Australian Aborigines, were considered to be the descendants of the earliest stages of cultural development, the Lower Palaeolithic and Middle Palaeolithic respectively (Sollas, 1911). Australian Indigenous cultures were therefore broadly viewed to be the exemplars of the earliest forms of human culture: "the hunter-gatherer estate on which, in world terms, agriculture was built," (Yen, 1989, pp.56).

This worldview has had several effects on scholarly and public perceptions of Indigenous Australians. First, as several Australian historians have recently argued (Gerritsen, 2008; Gammage, 2011; Pascoe, 2014), the notion of complexity and civilisation that the West held when Australia was 'discovered' and colonised inhibited their ability to consider the indigenous population of this foreign continent as anything more than 'primitives'. Second, it followed that Indigenous Australians, considered to be at the earliest stages of cultural evolution, had not undergone any significant social or economic change, remaining culturally static until the arrival of Western colonists (Mulvaney, 1981, pp.63–64; Hiscock, 2008, pp.4). This notion both delayed the development of prehistoric archaeology in Australia and fuelled the research of more recent decades: Australian archaeologists determined to display the dynamism of Australian pre-colonial history (e.g. Lourandos, 1997; Hiscock, 2008).

Third, labelled 'primitive', Indigenous Australians became at once the recipients and derivatives of the definition of 'hunter-gatherer'. As Mulvaney (1958a, pp.131) writes, "opinion concerning the aborigines [sic] frequently reflected current Old World philosophical beliefs, but there were times when European experience of the Australian native in the flesh influenced the formulation of theories about human origins, the State of Nature and primitive beliefs." Based on the assumption that these modern cultures were analogous to the Palaeolithic 'hunter-gatherers' of Europe, Australia (alongside Africa, Asia and America) was mined for the insights it could provide into the culture, economy and social structure of the forbearers of Western civilisation (Mulvaney, 1958b; Hiatt, 1996). It is at this period in the history of Western thought that the term hunter-gatherer was first coined in the English language, its definition derived both from 'Old World philosophical beliefs' and the observations of Indigenous Australians that these tempered. This resulted "in a circular and misleading argument more often than has been recognised," (Mulvaney, 1958b, pp.34). And the result of this circular process of definition is apparent in the continued accumulation of ethnographically observed practices into the definition of hunter-gatherer, without reconsideration of its meaning.

A prime example of this is found in the inclusion of anthropogenic vegetation burning into the universal concept of hunter-gatherer. In 1969 Rhys Jones published his provocatively-titled essay, 'Fire-stick farming'. This work considered Indigenous Australians' role in the environmental modification of Australia through controlled vegetation burning: a practice used variably to produce and maintain certain vegetation communities, to hunt, and to clear land. The paper subverted the perception of Indigenous Australians as passive Palaeolithic hunter-gatherers, instead characterising them as part-time food producers, growing their habitat and population through environmental manipulation. This rejection was, however, accompanied by a continuation of direct ethnographic analogy. Jones (1969, pp.228) perpetuated the assumption that Australian hunter-gatherers were unchanging by employing ethnographic examples of vegetation burning to paint the entirety of Australia and its pre-colonial history "for tens of thousands of years," with a single brushstroke. Further, Jones (1969, pp.227) incorporated the ethnographically observed practice of vegetation burning into his definition of hunter-gatherer by constructing a universal law: "its presence in most of the hunting and gathering and agricultural economies of the world implies that it has a high antiquity." This echoed the earlier and still often-cited writing of Stewart (1955, pp.116), who by using this same universality to counteract a lack of archaeological evidence acknowledged his direct kinship to "the scientific optimists of a century ago who expected to learn of cultural beginnings from surviving Stone Age peoples."

It is not, of course, a long bow to draw to suggest that early *Homo sapiens* and other hominins might have had the requisite knowledge and impetus to fire their landscape. However, to assume that this is the case is problematic on several levels. First, to assume the antiquity and universality of anthropogenic vegetation burning as a practice of landscape modification undercuts our own worth as archaeologists. Second, it creates a static and homogenous view of

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the past; obscuring the innovation and variation in past cultures (Hiscock, 2008, 2014). And third, the act of using fire to modify vegetation patterns has a specific historical, cultural and ecological context. Anthropogenic vegetation burning is unique in each of its instances, as it is both the affecter and the product of ongoing interactions between humans and their environment. It can be, as Jones (1969, pp.26–27) argues, an act of food production and a practice of habitat creation. Or it can be destructive; detrimental to the biodiversity of a region (Hiscock, 2014). The outcome is heavily reliant on a suite of ecological and cultural factors and is not consistent over time. It is, therefore, misleading to simply subsume the use of vegetation burning into the definition of hunter-gatherer. To do so universalises its use and outcomes in all early societies, irrespective of the distinct historical trajectories of those ethnographic cases from which it is inferred.

The unquestioning absorption of vegetation burning into the definition of hunter-gatherer is symptomatic of the broader progression of theoretical thought surrounding the origins of agriculture. The rejection of cultural unilinear evolution and scientific racism, which began almost at the moment that the theory entered the purview of archaeological thought (e.g. Boas, 1911), became widespread across the discipline in the 1960s (e.g. Braidwood and Willey, 1962; Binford, 1968; Flannery, 1968; Sahlins, 1968). However, conceptualisation of the origins of agriculture has been and, in most part, remains restricted by this theoretical framework.

Shifts in archaeological theory both mirrored a broader rejection of Enlightenment ideals across the humanities (Trigger, 2006, pp.446), and emerged organically within the discipline. First, as a response to an increasing awareness of the vast and diverse array of modern and archaeologically-documented societies that could not be positioned within the definitional confines of either hunter-gatherer or agriculturalist (Smith, 2001). Second, as a response to the archaeologically-supported hypothesis that much of this diversity is driven by environmental adaptation rather than diachronic cultural evolution (Rowley-Conwy, 2001). The gradual expansion of the hunter-gather/agriculturalist dichotomy to include a variously-defined in-between territory or 'middle ground', charted through the works of Rindos (1984), Ford (1985), Harris (1989, 1996), Zvelebil (1996), and Smith (2001), has responded to the first. This has also allowed archaeologists considering the origins of agriculture to move away from earlier progressive terms, such as 'complex hunter-gatherer' and 'proto-agriculturalist', and to consider the societies populating the middle ground as "stable long-term residents of an extremely broad and diverse temporal and evolutionary landscape," (Smith, 2001, pp.25). However, despite the movement away from progressive terms and the explicit rejection of the notion of 'progress,' the second has not been dealt with. Instead, the placement of this middle ground on an ever-expanding continuum between hunter-gatherers and agriculturalists continues to obfuscate the process of change within subsistence patterns; constraining thought in a linear manner. As this framework does not explain the development of subsistence systems, obscuring the range of drivers responsible for the diversity in subsistence practices, it is a barrier to further research into the development and spread of food-producing practices.

3.1. Niche construction theory

Instead, to examine the archaeological and ethnographic record of Sahul, this paper proposes to reconsider subsistence changes through a non-linear framework based on Rowley-Conwy and Layton (2011) model of 'niche construction' (see also Smith, 2007; Smith, 2011). Niche construction theory argues that all organisms engineer their environments. This process of engineering modifies their ecology and, therefore, the natural selection processes affecting themselves and the broader biotic community. Indeed, all humans passively modify their ecological niches through the removal of animals, plants and other resources from the environment. There are, however, a number of generalised activities performed by humans that can be considered 'active niche construction.' Rowley-Conwy and Layton (2011, pp.849) classify these into four categories: "the concentration of useful wild plants into accessible stands; small-scale plant cultivation; the burning of vegetation to encourage useful animals and plants; and hunting practices that modify animal populations." Each of these activities is deployed by humans in ecologically specific circumstances with the aim of food production and other short-term benefits. However, niche construction implies that these activities modify the environment alongside non-cultural agents and necessitates modification to the ecology that may not be an expected outcome. The "unstable" nature of niche construction, as Rowley-Conwy and Layton describe it, causes the ecological system and, therefore, the cultural system it supports to transform. Most instability in ecological niches does not domesticate, or genetically change, resources. However, when this does occur it allows for a new range of possibilities for human-environment interaction.

Whilst it is nigh impossible and perhaps counter-productive to remove earlier comparative terms such as 'hunter-gatherer', 'low-level food production' and 'agriculture' from our vocabulary, this model allows them to be extricated from any explanatory role in the change of human subsistence. Further, niche construction assumes that all human groups have the potential to produce and procure food. The concept of a passive hunter-gatherer at one end of the evolutionary continuum is irrelevant in the face of evidence for niche construction by non-human organisms. And, whilst Rowley-Conwy and Layton do describe a series of generalised behaviours, these are merely for explanatory purposes, as niche construction by its very nature explicitly understands that human practices of environmental modification can only be understood in ecologically and culturally specific trajectories. This allows for practices, such as the burning of vegetation, to be understood as ecologically and culturally specific tools, which may not necessarily have occurred universally or upon the first colonisation of a region. Ultimately, this model of niche construction allows for the reconceptualisation of change in human subsistence as a multiplicity of culturally and ecologically specific cultural 'evolutions'; an evolutionary tree, without a single trajectory or a set of implied stages of evolution.

4. Archaeological and ethnographic evidence

The archaeological evidence for landscape modification and subsistence within Sahul is rather limited in comparison to the region's rich ethnographic record (see Fig. 2). However, in order to properly consider the development and interaction of subsistence systems in Sahul since its colonisation 50–60,000 years ago (Clarkson et al., 2015), it is important to not allow the ethnographic record to frame our concepts of subsistence practices in earlier periods. This review will therefore be undertaken chronologically, focusing mainly on that data pertaining to plant use and landscape management in each time period (see Fig. 2).

4.1. Pleistocene (60–12,000 years ago)

First occupation of Sahul is dated to 50–60,000 years ago (Roberts et al., 1990, 1994, 1998; Clarkson et al., 2015); early occupation sites situated in temperate, tropical and high-altitude environments demonstrate relatively rapid population of the supercontinent (Groube et al., 1986; O'Connor, 1995; Turney et al.,

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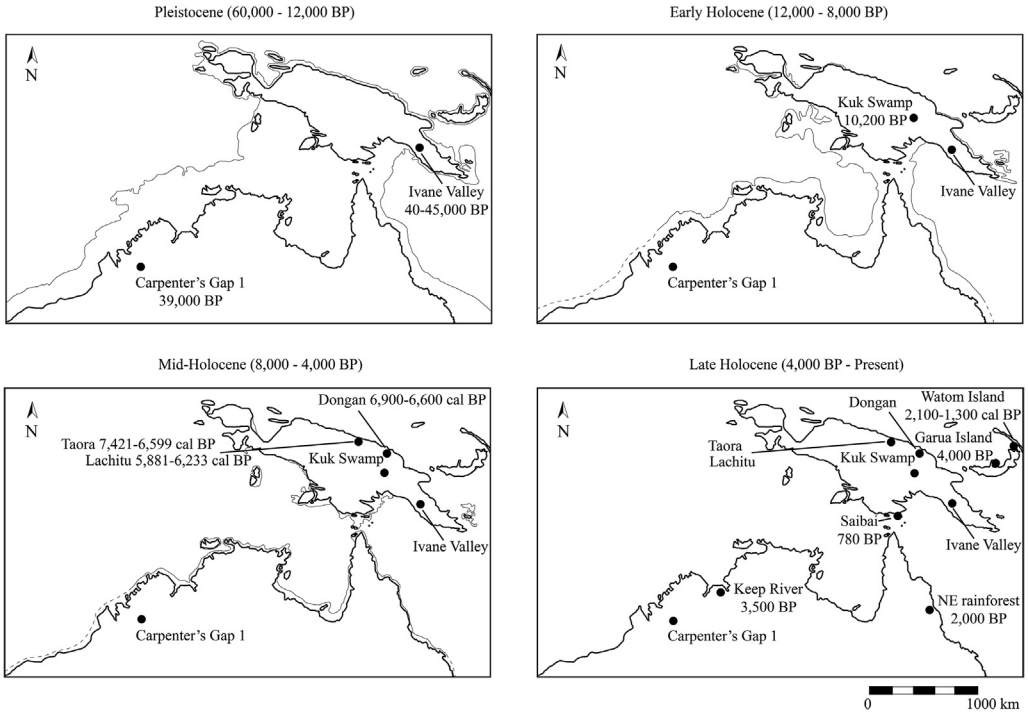

Fig. 2. Location of key sites mentioned in-text grouped chronologically. Each of these archaeological sites contains evidence of plant subsistence practices. Collectively they represent the entirety of the archaeological evidence of plant subsistence practices currently known for northern Sahul. Base map redrawn from van der Kaars (1991, Fig. 20). Pleistocene: sea level at 18,000 BP; Early Holocene: sea level at 12,000 BP; Mid-Holocene: sea level at 9000 BP; Late Holocene: sea level at present. Drawn by X. Carah and K. Norman.

2001; Bowler et al., 2003; Leavesly and Chappell, 2004; Summerhayes et al., 2010; David et al., 2011). Whilst subsistence data for the Pleistocene is patchy at best, evidence of plant exploitation in this period has been recovered from both the New Guinea highlands and the Kimberley region of northwestern Australia (see McConnell and O'Connor, 1997; Summerhayes et al., 2010).

In highland New Guinea, where initial occupation in the Ivane Valley is dated to between 49,000 and 43,000 cal BP, both the charred remains of a wild variety of pandanus and *Dioscorea* sp. yam starch grains have been recovered from occupation layers dated from 45,000–40,000 cal BP (Summerhayes et al., 2010). This evidence has been used by Summerhayes et al. to suggest early foraging populations in this region were frequenting the highlands to "guarantee a high return in plant fat and protein [from pandanus], to complement local animal foods, the starch-rich yams from lower altitudes, and those foods not preserved in the archaeological record."

At a comparative time period (c.39,700 ± 1000 cal BP) in north western Australia, macrobotanical remains of the arboreal *Terminalia* spp. fruit have been recovered from Carpenter's Gap rock-shelter (McConnell and O'Connor, 1997). Whilst McConnell and O'Connor's analysis of the subsistence practices represented by the Carpenter's Gap macrobotanical assemblage is rather tentative in its conclusions, it appears that several plants recovered from this site during the Pleistocene were exploited as part of the population's diet. This included fruits (*Vitex glabrata*, *Ampelocissus acetosa*, *Adansonia gregorii*, *Terminalia* spp.), roots and tubers (Cyperaceae, *Vitex glabrata*, *Ampelocissus acetosa*), and grass seeds.

Alongside the archaeobotanical evidence for occupation and subsistence practices in the Ivane Valley, palaeoenvironmental data from Ivane Valley Core A has been used to suggest the initiation of landscape modification in the New Guinea highlands (Haberle, 2003, 2007; Fairbairn et al., 2006; Summerhayes et al., 2010; Haberle et al., 2012). The highland region, as Fairbairn et al. (2006, pp.376) note, "is analytically useful when trying to disentangle fire causality in Sahul," as its landscape has "limited combustibility," making it "unlikely to have supported natural fires." For this reason, the onset of micro-charcoal accumulation at Kosipe Swamp between 41,000 and 38,000 cal BP can be attributed to anthropogenic vegetation burning and clearance (Fairbairn et al., 2006; Summerhayes et al., 2010). Anthropogenic vegetation burning is also evident in several other areas of the highlands in the Pleistocene from c.35,000 BP and continuing into the Holocene (Hope et al., 1988; Haberle, 1998, 2003; Haberle et al., 2001; Fairbairn et al., 2006). Whilst similar records have been used in Australia to suggest the onset of regional vegetation burning, the pyrophytic nature of the Australian environment, subject to regular natural burning events since the Tertiary, makes distinguishing between natural and anthropogenic fire events difficult (Bowman, 2003, pp.6–7). In their recent review of pan-Australian palaeoenvironmental records, Mooney et al. (2011, pp.30) contend that "there is no fundamental shift in the composite charcoal record," which might indicate the initiation of landscape burning by Indigenous Australians.

Evidence for plant use from the lowlands of mainland New Guinea is restricted to the identification of *Canarium* spp. nutshell in the Sepik-Ramu region at c.20,000 BP (Yen, 1991; Fairbairn pers. comm. in Denham et al., 2009c, pp.34). Also recovered from archaeological sites in island Melanesia in the late Pleistocene and early Holocene (Spriggs, 1997, pp.55; Allen, 2000, pp.156; Wickler, 2001, pp.236), *Canarium* spp. is argued to have been translocated alongside movements of people into the Bismarck Archipelago and further afield (Swadling and Hide, 2005, pp.306). Similar arguments for the translocation of the cuscus (*Phalanger orientalis*) into New Ireland have been put forward, with Flannery and White

(1991) suggesting the human-assisted dispersal of the species based on its appearance in the archaeological sites of Matenkupkum and Buang Merabak c.23,500–20,000 BP (Summerhayes, 2007; Heinsohn, 2010). However, in the absence of evidence for pre-human habitat ranges of either species, these arguments are not without their limitations (Leavesly, 2006, pp.196). Starch residues on lithic artefacts from Kilu Cave in the northern Solomon Islands suggest the use of *Colocasia* spp. and *Alocasia* spp. from earliest occupation, c.28,000 BP (Loy et al., 1992).

4.2. Holocene (12,000 years ago to present)

During the early Holocene, the macrobotanical remains recovered from both Carpenter's Gap and the Ivane Valley remain relatively consistent (McConnell and O'Connor, 1997; McConnell, 1998; Summerhayes et al., 2010). The plants exploited at Carpenter's Gap vary with climatic fluctuations into the late Holocene.

Within the Upper Wahgi Valley in the New Guinea highlands, archaeological excavations at Kuk Swamp document a series of pits, runnels, stake- and post-holes in the natural palaeochannels c.10,000–9000 cal BP (Denham et al., 2004). The use of these natural palaeochannels and the presence of taro (*Colocasia esculenta*) and yam (*Dioscorea* sp.) starch on lithic artefacts has been used by Denham et al. (2004, pp.843) to infer that highland populations were "planting and digging … [constructing] localised overland flow … and staking plants … within a cleared plot." By c.6900–6400 cal BP, Denham et al. (2003) argue this process of planting can be understood as agriculture, with evidence pointing towards both the construction of large-scale earthworks – a series of mounds and ditches – in this phase, and the deliberate planting of bananas within this artificial landscape, as indicated by a dense Musaceae phytolith horizon present in an anthropogenic grassland context. Artificial ditching is present in other wetlands in the Upper Wahgi Valley in the mid-to late Holocene and in the mid-altitude Ruti Flats of the Sepik-Ramu region, which was sealed by volcanic tephra c.3400 BP (see Harris and Hughes, 1978; Gillieson et al., 1985; Golson, 1997, 2002).

Direct archaeological evidence for plant-based subsistence practices in lowland New Guinea during the Holocene is somewhat sparse. Archaeobotanical analysis of Dongan, a site in the Sepik-Ramu region of New Guinea, has led Swadling et al. (1991; see also Swadling and Hide, 2005) to suggest that arboriculture was practised in this region from as early as 6500 BP. However, reviewing the archaeobotanical data from this site, Fairbairn (2005; Fairbairn and Swadling, 2005) argued the presence of economic species linked to arboriculture in the ethnohistoric record (*Canarium* spp., *Cocos nucifera*, *Pandanus* spp.) could not be used to assume cultivation. "It is impossible to say from the assemblage if local communities intervened in plant growth to plant, cultivate or tend tree and other crops or if they simply collected them from unmanaged vegetation," (Fairbairn, 2005, pp.492). Archaeobotanical analysis from other rockshelters in this region, Taora and Lachitu, have yielded similar assemblages and whilst claims for lowland vegetation burning have been made, the presence of micro-charcoal from anthropogenic rather than natural burning is much harder to identify in the lowland region (Hope and Tulip, 1994; see Haberle et al., 2001; Fairbairn, 2005).

Lentfer and Torrence (2007) were able to identify the practice of anthropogenic burning occurring on the lowlands of Garua Island, New Britain, in the late Holocene. A phytolith assemblage from the island, stratified by volcanic eruptions, suggests the interruption of natural forest recovery post-eruption through vegetation burning with populations maintaining anthropogenic grassland environments for more than 4000 years. This process of landscape modification, not apparent in earlier phases, is suggested to have been continued without great change, excepting the introduction of the *Caryota* sp. palm, despite the arrival of Lapita populations on the island. This arrival is denoted by the inclusion of Lapita pottery in the archaeological record, an event dated in other parts of the Bismarck Archipelago to c.3300 cal BP (Summerhayes, 2007). However, a "quantum shift in the degree of human interference" does occur until after 1000 BP, a pattern Lentfer and Torrence (2007, pp.102) suggest "most probably represents sedentary communities supported by cultivation."

A similar study conducted by Lentfer and Green (2004) on nearby Watom Island has been argued to suggest the practice of gardening during late Lapita settlement at Reber-Rakival, 2100–1300 cal BP (see also Fenwick et al., 2011). Increases in the concentrations of charcoal and microfossils during this period, including an abundance of phytoliths from grass, Musaceae and secondary forest species, led Lentfer and Green (2004, pp.84) to argue that the site was a garden environment, maintained "in a state of flux throughout the entire occupation phase, alternating between fallow regeneration and cultivation." Further, the postulated presence of solely Eumusa section banana phytoliths within this anthropogenic environment may indicate their introduction to the island as cultivars. However, their exotic status remains to be confirmed (Denham and Donohue, 2009, pp.20).

In mainland New Guinea there is no evidence for the arrival of Lapita pottery or Austronesian populations until 300 years after its first appearance in the Bismarck Archipelago with sites dating to c.3000 cal BP on the north coast and 2900–2500 cal BP on the south coast (McNiven et al., 2011; Gaffney et al., 2015). Pig bones, a potential marker of Austronesian spread into Melanesia, have been suggested to date to much earlier periods at some sites on mainland New Guinea (White, 1972; Bulmer, 1975, 1982, pp.187; Gorecki et al., 1991). These dates, however, have come under sustained criticism: researchers argue the remains yield from dubious stratigraphy (Kirch, 2000, pp.125; O'Connor et al., 2011), are not actually pig (O'Connor et al., 2011), or simply do not make sense in the regional picture (White and O'Connell, 1982, pp.188–189). Recent genetic analysis by Larson et al. (2007; cf. Matisoo-Smith, 2007) supports this criticism.

Several other animals, including the chicken, dog and rat, may have also arrived in Melanesia with the movement of Austronesians into this region in the late Holocene (Kirch, 2000). With the exception of the dog, which only appears in later archaeological contexts in the Pacific, these animals have been observed in Lapita sites and appear to have genetic origins, alongside Austronesian populations, in mainland and island Southeast Asia (Matisoo-Smith and Robins, 2004; Savolainen et al., 2004; Matisoo-Smith, 2007; Beavan-Athfield et al., 2008; Storey et al., 2010, 2012; Oskarsson et al., 2012; Skoglund et al., 2016). The Australian dingo is also potentially linked to this dispersal. Genetic evidence suggests that it originated in mainland southeast Asia with archaeological evidence placing it in southern Australia by 3705 ± 225 cal BP (Milham and Thompson, 1976; Savolainen et al., 2004; Oskarsson et al., 2012). However, a lack of evidence for domestic dogs in either island Southeast Asia, New Guinea or the Torres Strait, prior to 2921–3075 cal BP in Timor-Leste (Gonzales et al., 2013), means details as to the process of arrival are, at this point, speculative.

The earliest known archaeological site in the Torres Strait, Badu 15, dates to 8850 cal BP (David et al., 2004; see Fig. 3). Through the mid-Holocene, occupation in the Torres Strait remained constrained to the Near Western Islands, intensifying with the beginnings of turtle and dugong exploitation c.4000 BP (David et al., 2004; McNiven et al., 2006; Crouch et al., 2007; Wright and Jacobsen, 2013; Wright et al., 2014; Crouch, 2015; Weisler and McNiven, 2016). Occupation of the Eastern (Carter et al., 2004) and Top-Western Islands (Barham, 1999) commenced

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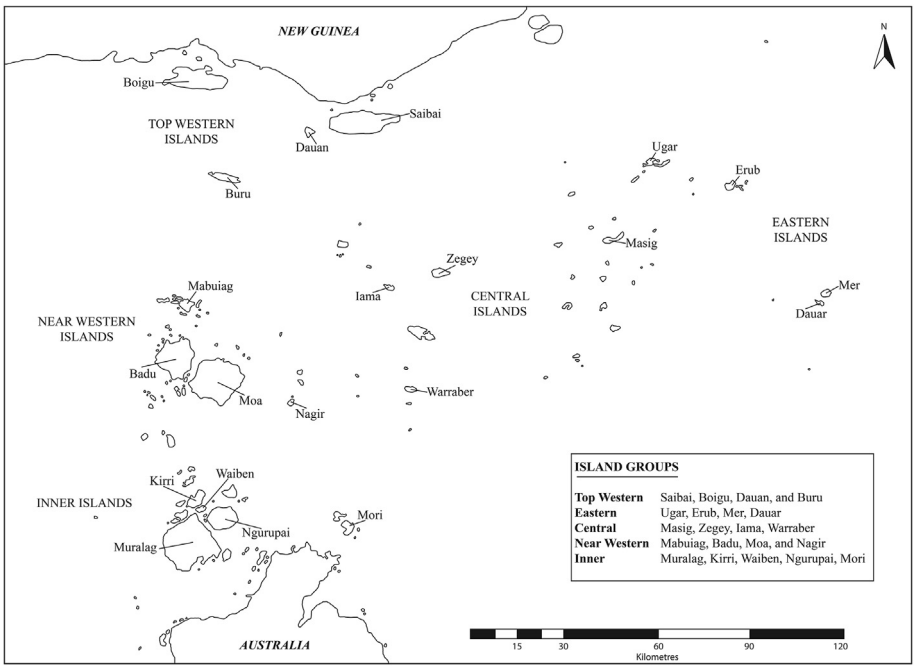

Fig. 3. Map of Torres Strait Islands, organised into groups according to National Museum of Australia (2003). Drawn by X. Carah and K. Norman.

contemporaneously with the stabilisation of sea levels and cessation of island formation in the late Holocene.

On Dauar Island, eastern Torres Strait, phytolith analysis suggests first occupation included the use of a potentially exotic cultivar, the banana (Parr and Carter, 2003). At the site of Ormi, Parr and Carter (2003) identified the presence of three Musaceae leaf phytoliths in what was otherwise an open broad leaf foreshore habitat c. 2600–2000 cal BP. As wild bananas only grow within or on the margins of tropical forests, they argued the banana identified at the site was not endemic to the island's flora and, therefore, suggested introduction and cultivation of the species. However, the sites (Ormi and Sokoli) considered in Parr and Carter (2003) phytolith study were both settlement sites situated in foreshore habitats. This suggests that the presence of open broad leaf forest in the assemblages does not preclude the presence of other vegetation communities, including tropical forest vegetation, on Dauar Island. Therefore, the presence of banana leaf phytoliths at Ormi may be demonstrative of banana cultivation c.2600 cal BP or it may simply represent the use of banana leaves at the site, which were gathered from wild stands on a different part of Dauar Island or further afield (Denham and Donohue, 2009, pp.20). Equally, there is little evidence to suggest the later presence of *Ipomoea* sp., *Dioscorea pentaphylla*, or "tentatively identified" *Cocos nucifera* in the Dauar Island assemblages is representative of anything more than the use of edible species (Parr and Carter, 2003, pp.138).

The earliest unambiguous evidence for horticultural practices in the Torres Strait comes from a relict mound-and-ditch field system on Saibai Island, where a *terminus post quem* of 780 ± 70 BP was procured from an underlying midden deposit (Barham and Harris, 1985, pp.264; 274–277). There is, however, evidence for the commencement of anthropogenic landscape modification on the island beginning slightly earlier. Barham (1999) identified a significant increase in swamp sedimentation across Saibai after c.1200 BP, which is suggestive of vegetation clearance on the adjacent claylands.

Evidence of horticultural practices in the form of constructed mound-and-ditch field systems, linear and curvilinear raised mounds, and, to a lesser degree, stone walls and boundary markers are also present in the Eastern and Near Western Islands of the Torres Strait (Harris, 1977; Harris and Laba, 1982; Barham and Harris, 1985; Barham, 1999; Barham et al., 2004, pp.47). However, none of these earthworks have been securely dated and those from the Near Western Islands, closest to Cape York, are found in relation to post-missionary contact settlements (Barham et al., 2004, pp.46–47). This suggests the possibility of a much more recent history and a connection to colonial migrants from the Pacific Islands. Due to this potentially relatively recent history for horticulture in the Torres Strait, Harris (1995, pp.854) argued that the Torres Strait "functioned neither as barrier to, nor as a bridge for, the 'transmission' of agriculture into Australia." Whilst this assertion requires further archaeological investigation, several materials, technologies and ideas were traded across the Torres Strait into Northern Australia during the Holocene, including the outrigger canoe, stone raw material (Barham and Harris, 1985) and, potentially, the dingo (Rowland, 1987; Barham et al., 2004; McNiven and Hitchcock, 2004).

Evidence for subsistence and landscape practices in northern Australia during the Holocene is also sparse. However, archaeobotanical investigations carried out in the Keep River region of Western Australia and the northeastern Queesnland rainforest do allow some insight into subsistence practices in the mid-to late Holocene. In the Keep River region, the remains of heavily fragmented *Persoonia falcata* and *Buchanania obovata* seeds from c.3500 BP in several archaeological sites (Jinmium, Granilpi and Punipunil) have been argued by Atchinson et al. (2005) to denote the production of storable pastes and cakes, as these fruits were known from ethnohistoric records to be pounded and stored in paperbark in this form. However, as the fragmentation of these charred seeds may simply be due to taphonomic processes, residue analysis on grinding technology is required to confirm the antiquity of this ethnographically observed practice.

In the northeastern Queensland rainforest, multi-proxy archaeological investigations carried out by Cosgrove and colleagues (Cosgrove, 1996; Cosgrove et al., 2007; Ferrier and Cosgrove, 2012; Ferrier, 2015; Field et al., 2016) have suggested the modification of this environment to allow its increased

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occupation during the late Holocene (contra Bailey et al., 1989). Whilst rainforest expansion occurred in this region alongside the climatic optimum c.8500 BP, archaeological evidence does not suggest widespread use of the rainforest environment until c.2000 BP (Cosgrove et al., 2007). This late Holocene occupation is facilitated by the exploitation of starch-rich toxic walnuts, carbonised fragments of which were initially recovered from archaeological deposits c.2600 BP. These and other economic species are now found grouped in open and sclerophyll forest pockets amidst rainforest vegetation and are recorded to have been maintained through seasonal vegetation burning in the historical period (Field et al., 2016). Phytolith analysis, conducted by Field et al. suggests that the sclerophyll pocket at the Urumbal archaeological site existed and was, therefore, likely maintained for at least the last 2000 years. This suggests the historic practice of vegetation burning had an extended history.

4.3. Ethnohistoric record

A diverse range of subsistence and landscape modification practices have been documented in ethnographic and historical records since the European 'discovery' of Sahul, suggesting a variety of human-environment interactions across the super-continent. In Australia, ethnographic, ecological and historic evidence has been produced for a range of subsistence practices:

- Vegetation burning (Jones, 1969, 1975, 1980b, 1980a; Haynes, 1985; Bowman and Latz, 1993; Russell-Smith et al., 1997; Enright and Thomas, 2008; Gammage, 2011);
- Water management, including damming to artificially maintain and grow vegetation communities (Tindale, 1977, pp.347; Barber and Jackson, 2015), and the construction of earth works to facilitate in the trapping of eels and fish (Robinson, 1841; Lourandos, 1997, pp.65);
- And plant cultivation, including yam and millet seed harvesting used to support semi-sedentary populations (Mitchell, 1839; Grey, 1841; Sturt, 1849; Hallam, 1989; Gammage, 2011, pp.293–304).

Many ethnographic and historic sources also document Indigenous Australian populations hunting and gathering from their local environments with little recorded environmental manipulation.

In New Guinea and across the Torres Strait, ethnographic and historic sources document a range of subsistence practices:

- Intensive agricultural production (including deforestation, tillage, grid-iron ditching, mound building, drainage, slope retention practices and segregation of crops), "confined for the most part" to the highlands (Powell, 1976; Allen, 1977, pp.171);
- Shifting gardening/horticulture, using wild and domestic plants (Allen, 1977; Harris, 1977; Barham and Harris, 1985; Sillitoe, 2002; Barham et al., 2004);
- Sago cultivation/gathering in the freshwater swamps of the northern and southern lowlands (Powell, 1976, pp.112–113; Allen, 1977, pp.171; Ohtsuka et al., 1984);
- And hunting, gathering and fishing, including marine specialisations (Allen, 1977; Harris, 1977; Sillitoe, 2002).

Whilst most communities implemented a combination of these subsistence practices, the extent of each practice was restricted by resource availability and other environmental parameters. Across the Torres Strait, geographic-variation is particularly prominent. The reliance of populations on horticultural production was suggested by Harris (1977, pp.422) to be "varied along a [decreasing] gradient from north to south."

5. Discussion

From both the archaeological and ethnographic evidence presented, it is clear that the 'Neolithic problem', the notion of an expansive agricultural frontier resisted by northern Australian hunter-gatherers, is not supported. First, as often noted, the diversity of subsistence practices documented in the archaeological and ethnohistoric record bears little resemblance to the hunter-gatherer/agriculturalist divide once identified by Moresby (1876). Second, as Harris (1995) contended, there is little archaeological evidence to suggest an extended period of horticultural practice in the Torres Strait or the New Guinea lowlands proper, which might have been actively rejected by northern Australian Indigenous populations. Indeed, the only unambiguous archaeological evidence for horticultural practices in this region, the dated construction of a mound-and-ditch field system, comes from an island less than 5 km off the coast of New Guinea and dates to the last millennia (Barham and Harris, 1985, pp.264; 274–277). This absence of evidence for earlier horticultural practices could, of course, simply be a product of archaeological bias. Indeed, the lowlands of New Guinea and the Torres Strait have received relatively little archaeological attention (Walter and Sheppard, 2006, pp.137–144), and have often been devoid of the multi-disciplinary and archaeobotanically-focused studies required to disentangle the difference between the collection of unmanaged plants and the harvesting of cultivated varieties (Fairbairn, 2005). However, this absence of evidence could also be representative of the pre-colonial history of this region. Horticultural cultivars and practices may have only entered the economy of Torres Strait Islanders relatively recently.

The direct sedimentation from claylands into the adjacent swamp systems on Saibai Island, occurring after c.1200 BP, arguably offers a reliable timeframe for the commencement of horticultural practices in the Top-Western Islands (see Fig. 3). As Barham (1999, pp.98) contends, this onset of increased sedimentation is "an unexpected outcome" when "viewed as a function of actors relating to relative sea level or autogenic changes in swamp ecology and sedimentation." However, if construction and use of horticultural field systems on the swamp-adjacent claylands were to have commenced following c.1200 BP, it would be an expected "sedimentary consequence" of this. If this relationship is accepted, the later date for construction recorded by Barham and Harris (1985), 780 ± 70 BP, may relate to an extension of earlier mound-and-ditch field systems or the beginning of their construction following an extended period of vegetation clearance for settlement and other subsistence practices. Both these options, however, suggest that the commencement of horticultural practices on Saibai post-dates its initial occupation c.2100 BP, with commencement no earlier than 1200 BP.

Barham et al. (2004, pp.52) asserts that this relatively late date for the incorporation of horticultural practices into the economy of the Top-Western Islands is indicative not of a late appearance of cultivars in the Torres Strait, but of a late appearance of 'intensive' horticultural practices. Indeed, they argue that populations entering the Top-Western and Central Islands of the Torres Strait, following late Holocene sea level stabilisation and island formation, were "maritime in focus," but likely to have posessed some cultivars and to have supplemented an otherwise coastal hunter-gatherer economy with "small-scale swidden cultivation." This practice, Barham et al. argue became 'intensive' as local carrying capacities were reached, especially on the smaller Top-Western, Central and Eastern Islands. However, the mound-and-ditch field systems present on Saibai, other Top-Western and Western Islands, and the

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adjacent areas of lowland New Guinea are found only in geographic locations with "lowland extensive enough to reward cultivation, but where wet season flooding by either fresh or brackish waters represents a problem that might be mediated by 'raised beds' separated by ditches" (Barham et al., 2004, pp.46). Therefore, it is more likely that they are representative of an adaptation of horticultural practices to environmental conditions, rather than an 'intensification' of earlier small-scale practices.

Harris' (1995) alternative, that horticulture is a relatively recent import into the lowlands of southern New Guinea and, therefore, the Torres Strait, is supported both by the archaeological evidence available and the ethnographic patterning of horticultural practices across the Torres Strait. Indeed, a relatively late incorporation of horticultural practices into the economy of the Top-Western Islands is consistent both with the ethnographic decline in reliance on horticultural practices "along a gradient from north to south" (Harris, 1977, pp.422), and the possible Pacific Islander origin for those horticultural field systems found in relation to post-missionary contact settlements on the Western Islands (Barham et al., 2004, pp.46–47). Whilst the little archaeological evidence available for this region requires caution in any interpretation, the suggestion that there was a large temporal window within which cultivars and horticultural practices were a significant part of the economy of Torres Strait Islanders and yet rejected by Indigenous Australians is not supported and should not be assumed.

5.1. Reconstruction: niche construction theory

With the 'Neolithic problem' called into question, it is possible to reconsider these data through the lens of niche construction theory. This framework allows for the observation of a variety of 'active niche-construction' practices across northern Sahul (Rowley-Conwy and Layton, 2011, pp.849; see Table 1). Whilst all of these practices produce a greater yield of desirable plant and/or animal species within a given environment, only a small number fall into the purview of small-scale or agricultural plant cultivation. It is the interaction of these practices of active niche construction within varied ecological niches and climatic conditions that has produced changes in subsistence systems over time in this region.

5.1.1. Anthropogenic vegetation burning

One of the most seemingly ubiquitous practices noted in the ethnohistoric record of northern Sahul is that of vegetation burning. Palaeoenvironmental evidence of its use, to varying levels of certainty, has been recovered in several environments throughout the region. However, the practice of anthropogenic vegetation burning is not always an element of the colonising toolkit, and the implementation and outcome of this practice appears unique in both space and time.

The onset of anthropogenic vegetation burning in highland New Guinea occurred in the Ivane Valley approximately 5000 years (41–38,000 cal BP) after its first occupation (Summerhayes et al., 2010). Landscape management practices developed over time. The use of vegetation burning is also evident in other areas of the highlands beginning c.35,000 BP and continuing into the Holocene (Fairbairn et al., 2006). However, considering the delay between the initial occupation and first anthropogenic firing of the Ivane Valley, it appears erroneous to assume that this practice can be used to indicate the arrival of humans in these localities (e.g. Haberle, 1998).

The ethnographic work of Russell-Smith et al. (1997) in the Gundjeihmi and Kunwinjku language areas of western Arnhem Land describes an Indigenous practice of vegetation burning used to hunt animals, reduce fuel load and curate spaces required for economically important vegetation growth. A seasonal practice – regulated both by the heavy rainfall of the wet season and the intensified aridity of the late dry season – vegetation burning in western Arnhem Land is centred around the extensive lowland floodplains, where low-intensity burns in the early to mid-dry season allow for the regeneration of perennial grasses, sedges and aquatic geophytes. This systematic burning regime affects the natural fire regime not in magnitude but in its nature. Smaller vegetation burns undertaken by Indigenous people in a particular season prevent larger fire events and construct a more productive and predictable landscape. The freshwater floodplains over which these burns are conducted were only formed in the last two millennia, a product of gradual progradation and natural levee formation following the earlier marine transgression (Woodroffe et al., 1985, 1986, 1988; Bourke et al., 2007; Brockwell et al., 2009, pp.58). Therefore, whilst humans occupying this region over the

Table 1
Table of known active niche construction practices occurring during the pre-colonial history of northern Sahul. *Potentially: The absence of evidence for pre-human habitat ranges of either *Canarium* spp. or *Phalanger orientalis* means that the translocation – and replanting, in the case of *Canarium* spp. – of these species may not have occurred.

Active niche construction practice	Location	Date commenced	Reference
Anthropogenic vegetation burning	Ivane Vallley and highlands of New Guinea	41,000–38,000 cal BP (Ivane Valley); After c.35,000 BP (Elsewhere)	(Summerhayes et al., 2010); (Hope et al., 1988; Haberle, 1998; Haberle et al., 2001; Haberle, 2003; Fairbairn et al., 2006)
	Garua Island	Before c.4000 BP	(Lentfer and Torrence, 2007)
	Northeastern Queensland rainforest	c.2000 BP	(Field et al., 2016)
Translocation of plants	Ivane Valley (Yam, *Dioscorea* spp.)	c.45,000–40,000 cal BP	(Summerhayes et al., 2010)
	Island Melanesia (Galip nut, *Canarium* spp.)*	Before c.13,000 BP (Manus Island); c.10,000 BP (Buka Island); c.8000 BP (New Ireland)	(Spriggs, 1997, pp.55); (Wickler, 2001, pp.236); (Allen, 2000, pp.156)
Translocation of animals	New Ireland (Cuscus, *Phalanger orientalis*)*	c.23,500–20,000 BP	(Summerhayes, 2007; Heinsohn, 2010)
Small-scale plant cultivation	Island Melanesia*	Before c.13,000 BP (Manus Island); c.10,000 BP (Buka Island); c.8000 BP (New Ireland)	(Spriggs, 1997, pp.55); (Wickler, 2001, pp.236); (Allen, 2000, pp.156)
	Kuk Swamp	c.10,000–9000 cal BP	(Denham et al., 2003; Denham et al., 2004)
Agricultural plant cultivation	Kuk Swamp and highlands of New Guinea	c.6900 to 6400 cal BP (Kuk Swamp); (Elsewhere in the Upper Wahgi Valley); c.3400 BP (Ruti Flats)	(Denham et al., 2003; Denham et al., 2004); (Harris and Hughes, 1978; Golson, 1997, 2002); (Gillieson et al., 1985)
Adoption and husbandry of domestic animals	Mainland Australia (Dingo, *Canis lupus dingo*)	Before c.3705 ± 225 cal BP	(Milham and Thompson, 1976; Savolainen et al., 2004; Oskarsson et al., 2012)
	Island Melanesia and New Guinea lowlands (Chicken, *Gallus gallus domesticus* and pig, *Sus scrofa domesticus*)	Post-Lapita colonisation	(Matisoo-Smith, 2007; Beavan-Athfield et al., 2008; Storey et al., 2010; Storey et al., 2012)

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last 50–60,000 years may have been engaged in practices of vegetation burning (Hope et al., 1985, pp.331; cf. Nanson et al., 1993), such landscape modification, altered by different ecological circumstances and varying patterns of human occupation, would have been different in both practice and effect (Russell-Smith et al., 1997, pp.177–179).

In the lower montane rainforests of the Upper Wahgi Valley, highland New Guinea, there is evidence of anthropogenic vegetation burning from c.20,000 BP, producing a shift in rainforest composition towards secondary light-demanding species and grassland expansion (Denham and Haberle, 2008, pp.485). Denham and Haberle argue that this anthropogenic vegetation burning would have opened grassland patches within the rainforest vegetation, allowing populations greater access to its diverse arboreal and faunal resources (Groube, 1989, pp.298). "As patches became maintained foci of activity, so too the resources within those gaps – including herbs (*Musa* spp.), tuberous plants … grasses (*Saccharum* spp. and *Setaria palmifolia*), and a wide variety of leafy vegetables – were brought under increasing management," (Denham and Haberle, 2008, pp.488). By 7000 BP grassland in this region had expanded significantly, a pattern maintained until present (Denham and Haberle, 2008, pp.485). Considered through the framework of niche construction, it can be argued that whilst vegetation burning was initially employed to facilitate hunting and access to arboreal resources, it created an unstable niche and caused a decline in rainforest, forcing the cultural system it supported to transform. Indeed, vegetation burning may have occurred to the detriment of forest resources: depletion of rainforest habitat decreasing the availability of plant and animal resources once used by the Kuk Swamp population (Denham and Haberle, 2008, pp.490). However, the changes in the niche also opened up further possibilities. The grasslands and volcanic soil further enriched through firing became ideal for the growth of many economically-important species, including some of those arboreal species no longer growing in close proximity.

In northeastern Australia, there is archaeological evidence to suggest Indigenous populations also practised vegetation burning, opening patches within the local rainforest beginning c.2000 years ago (Field et al., 2016). This practice, coupled with the planting and maintenance of economic species and advancements in exploitation of toxic walnuts, appears to have facilitated the colonisation of a previously unreceptive environment. This suite of active niche construction practices shares many similarities with that occurring earlier in the New Guinea highlands. The maintenance of openings in these rainforest environments allowed both communities unencumbered access to otherwise dispersed economic species of plants and animals. However, the continued translocation of plants outside of their geographic range into the higher altitudes of the New Guinea highlands created an opportunity not necessarily possible in the low altitude northeastern Queensland rainforest.

5.1.2. Niche transformation: Upper Wahgi Valley

Taro, yams and other cultigens identified as part of the food-production practices at Kuk Swamp are known ethnographically to be used across Sahul today, in both domesticated and wild states. Though their use is hard to detect archaeologically, it is likely that many of these plants were also used as part of an array of subsistence practices employed by populations across the lowlands of New Guinea and northern Australia since the Pleistocene. For many tropical cultivars, where domestication does not necessarily change the reproductive practices of the species involved, it is not always the earliest case of cultivation that will cause domestication but that which takes the plant out of its geographic range (Vrydaghs and Denham, 2007, pp.3). This is because the separation of the species from its non-tended counterparts allows humans to both control its reproduction and select for beneficial phenotypic traits. It is therefore possible that the subsistence practices that first brought the yam, taro and banana into the highlands in the early Holocene were employed across Sahul. The morphological and genetic changes that occurred in the highlands were a product of translocation (Yen, 1995; Denham and Barton, 2006). Summerhayes et al. (2010) research in the Ivane Valley suggests that it is highly likely that populations frequenting the region in the Pleistocene to harvest pandanus nuts – and potentially to extricate themselves from the threat of malaria (Kirch, 2000, pp.83–84) – were supplementing their diet with *Dioscorea* spp. yams grown in lower altitudes. Whilst Denham et al. (2004, pp.849) have suggested that the occurrence of these plants at higher altitudes in the early Holocene may be due to their natural movement during climate amelioration, the lack of wild *Dioscorea* spp. at this altitude suggests that at least the yam was transported to this region by humans (Yen, 1995, pp.836). The Holocene climate amelioration may, however, have been a necessary ingredient to allow for the cultivation of these species in the highland environment.

This translocation does not, however, necessitate the agricultural practices of Kuk Swamp to have originated in the lowlands as Golson (1977, 2007) and Yen (1995, pp.842–843) have suggested. Indeed, the translocation of yam, taro and banana into the constructed highland environment may have been the catalyst for such practices. As Gott (1982, pp.65) research in southern Australia demonstrates, relatively simple practices such as the gathering of geophytes, allowed for the increased productivity of such plants. The thinning out of the patch and aeration of the soil, which occurred through the digging process, allowed for greater yields of geophytes, with increasingly large vegetative organs. With the low-intensity year-round rainfall, the frequent burning, and rich, volcanic soils of Kuk Swamp, these changes would have been both magnified and, without neighbouring un-tended wild populations, easily controlled by humans. As these plants were selected for their size and palatability, they may also have been planted on naturally occurring palaeochannels within Kuk Swamp (Denham, 2007, pp.83–86). "Water-tolerant plants, e.g. taro (*Colocasia esculenta*), were plausibly planted in damp conditions along the edges and in the bases of the runnels, and water-intolerant plants, e.g. sugarcanes (*Saccharum* spp.), bananas (*Musa* spp.), yams (*Dioscorea* spp.), *Setaria palmifolia* and mixed vegetables, were planted and staked on raised 'beds'," (Denham, 2007, pp.86). The possibility of morphological change through the choice of specific phenotypic traits and further tending would have increased the productivity of the newly developed and fertile grassland niches within the Upper Wahgi, potentially making them the central focus of subsistence practices. In this manner, the horticultural practices involved in the Upper Wahgi Valley food-production system may have developed alongside and, even, because of the advantageous domestication of the cultigens involved.

5.1.3. Niche transformation: coastal plains of southwestern Australia

The historically recorded use of *Dioscorea hastifolia* by the Nhanda-speaking populations occupying the coastal plains of southwestern Australia may also reflect the cultivation of yams. Compiled by Hallam (1989), historical records from explorers and, later, missionaries attest to the extensive food production practices employed in this fertile Australian environment. The Indigenous populations of this region tended and harvested extensive yam fields (up to 5–6 km in length and 2 km wide), as well as hunted and gathered local wetland and grassland resources, the latter of which were developed and maintained through controlled vegetation burning (Hallam, 1989, pp.140). This set of subsistence practices, focused on a yam species that required little to no

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preparation – it could be eaten cooked or raw (Hammond, 1933, pp.28) – allowed for a large population to occupy this region. As Sir George Grey (1841, pp.211) wrote, the coastal plains of southwestern Australia are "the most thickly populated district of Australia … and moreover one which had here been done to secure a provision from the ground by hard manual labour than I could have believed it in the power of uncivilised man to have accomplished." Both the mono-culture fields of yam, and the facilities constructed around them (pathways, wells and "superior huts") were in discord with the European views of the Indigenous population who produced them (Grey, 1841, pp.19; Hallam, 1989). However, many of the subsistence practices used to construct this niche – vegetation burning, yam tending and replanting, wetland and grassland exploitation – were also practised in other parts of Sahul (see Gott, 1982; Hynes and Chase, 1982; Chase, 1989; Jones and Meehan, 1989; Yen, 1989).

There are two alternate views for the development of this system of food-production. The first, suggested by Hallam (1989), is that this system was an indigenous development, its antiquity potentially extending into the mid-Holocene. As Hallam (1989, pp.144) writes, the archaeological evidence, from a survey of the Swan River coastal plains (Pearce, 1978), "confirms ethnohistorical evidence of large groups focused on the resources of swamps, lakes, and alluvial floodplains … from before the advent of backed-tool assemblages about 5000 bp." However, no further archaeological work has been completed in this region, which might confirm the cultivation or, indeed, use of *Dioscorea hastifolia* as part of this subsistence system. The second, posited by Gerritsen (1994a, 2008), suggests that *Dioscorea hastifolia* and many of the methods used to tend it arrived with Dutch explorers, who were deliberately left on the coast of western Australia in 1629 and absorbed into the Indigenous populations of the region. Gerritsen (1994a, 1994b) suggests this in the light of two factors. First, based on his own analysis of the Nhanda language from early historical records, he suggests 16% of its words were of Dutch derivation. And second, as *Dioscorea* spp. are typically tropical in range, he argues that they are out of place in temperate southwestern Australia (Gerritsen, 2008, pp.38). Instead, he suggests they are offshoots of *Dioscorea alata* transported alongside the Dutch from Java.

Critiquing the linguistic evidence for this latter interpretation, Blevins (1998, 2001) has dismissed Gerritsen's suggestion of Dutch influence. She instead contends that despite variations between Nhanda and that of other surrounding Aboriginal languages, "it is possible to show that most Nhanda words originate from a mother-language (called Proto-Pama-Nyungan) which was most likely spoken on the Australian continent between 3000 and 5000 years ago," (Blevins, 1998, pp.43). Preliminary genetic evidence for the *Enanthiophyllum* Uline section of the *Dioscorea* genus also runs counter to Gerritsen's assertion, suggesting that *Disocorea hastifolia* is most closely related to another Australian species of yam, *Dioscorea transversa* (Chair et al., 2016, pp.328). Therefore, a more parsimonious explanation for the temperate range of *Dioscorea hastifolia* might be found in the spread and contraction of Gondwanaland flora (Yen, 1993, pp.10; Lebot, 1999). A common ancestor of both *Dioscorea hastifolia* and *Dioscorea transversa* potentially spanned a much greater swathe of Australia before narrowing in geographic range to the more watered extremities of the continent.

Whilst, without further archaeological research, it is not possible to gauge the antiquity of the practices undertaken by the Indigenous populations of southwestern Australia during the nineteenth century, to question the Indigenous origin of such practices seems on current evidence akin to not believing them to be "in the power of uncivilised man," (Grey, 1841, pp.211). Nhanda-speaking Indigenous populations tended, protected and replanted *Dioscorea hastifolia*, producing an anthropogenic environment dominated by edible tubers on the alluvial floodplains of southwestern Australia. The lack of chemical defences displayed in *Dioscorea hastifolia* has further led Walter and Lebot (2003, pp.15) to suggest it may constitute a cultivar (see also Chair et al., 2016, pp.328–329). This is because, as yams regenerate from their tubers, edibility is not a beneficial trait in most non-anthropogenic environments (Rindos, 1984, pp.145–146).

5.1.4. Unstable adaptations

Across Sahul, several subsistence systems have been labeled with the term agriculture (Golson, 1977; Kirch, 2000; Denham et al., 2003; Gerritsen, 2008; Pascoe, 2014); some more readily accepted than others. Whilst this term can be useful in a comparative sense, it also obscures the differences in these subsistence systems, their development governed by the interaction of historically-produced cultural and ecological factors, rather than their stage of cultural evolution. Whilst the archaeological record does not allow for a complete interpretation of the development and expansion of subsistence systems in this region, it remains clear that the populations of the Upper Wahgi Valley and the Lapita cultural groups produced distinctive trajectories, in spite of their 'agricultural' label.

In the mid-Holocene, Upper Wahgi Valley subsistence practices – increasingly focused on the cultivation of domestic and wild plant species in artificial ditch and mound systems in Kuk Swamp – spread to other wetland systems within the valley (Harris and Hughes, 1978; Golson, 1997, 2002). By c.3400 BP ditch and mound horticultural systems were also present in the Ruti Flats, a mid-altitude grassland in the Western Highlands Province (Gillieson et al., 1985). An expansion of horticultural practices into new regions of the New Guinea highlands and its fringes may be indicative of population growth and expansion in this region. However, there is little archaeological evidence through which to evaluate whether further mid-to late Holocene expansion of populations and/or practices into the lowlands of mainland New Guinea occurred (Fairbairn, 2005). Rather genetic and linguistic proxy data demonstrate that the New Guinea highlands were isolated from a relatively early time (c.37ka), despite ongoing interaction between lowland populations and Indigenous Australians across the Arafura Shelf (Malaspinas et al., 2016, pp.512; Skoglund et al., 2016). Indeed, there are several factors that have impeded the movement of intensive agricultural practices and large populations out of the New Guinea highlands in the recent past. First, as discussed previously, the environment of the inter-montane highland valleys (including volcanic soils, much needed exposure to sunlight and the low-intensity year-round rainfall (Fyfe, 2009, pp.127)) is ideally suited to the practices developed there. Second, whilst the inter-montane valleys are ideal for horticulture, their surrounding environments, the upper montane and subalpine forests, and the steep ridges of the lower highland clines, are quite the opposite. Both the drop in temperature at higher altitudes, and the steep ridges, persistent cloud cover and increasingly monsoonal rainfall patterns at lower altitudes are unsuitable for the cultivars and horticultural practices of the inter-montane valleys (Golson, 2007, pp.120–121). Third, the highland region was, with the exception of some of the lower-lying valley systems, until recently malaria free (Müller et al., 2003). This not only allowed for the unencumbered growth of larger populations in the highlands, but also, discouraged these populations from vertical migration. Haemoglobinopathies, which through natural selection have become widespread in the malarious lowlands of New Guinea, are almost nonexistent in highland populations, allowing them little genetic immunity against the disease (Flint et al., 1986; Müller et al., 2003; Kazura et al., 2012). These unique environmental impediments would have been just as pertinent in the mid-to late Holocene and may

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have restricted New Guinea 'agriculturalists' to the highlands.

Whilst there is equally no archaeological evidence for the movement of cultivars or horticultural practices into lowland New Guinea, recent research by Gaffney et al. (2015) has demonstrated the presence of trade in both materials and ideas between the lowlands and the northern highland fringe in the late Holocene. Reanalysis of pottery excavated at Wanelek, an open site in the Bismarck Schrader Ranges, has identified the presence of both locally-produced and Lapita ceramics c.3000 cal BP. This not only suggests an early introduction of pottery, and the technical ability to produce it, into the northern highland fringe, but also interaction with Lapita cultural groups, expanding westward from the Bismarck Archipelago, either directly or indirectly through lowland populations. As Gaffney et al. (2015, pp.12) argue, the same network, which allowed for the movement of materials and ideas into the highlands may have "enabled the movement of cultivars" out of the highlands. This prospect is not implausible. However, it is likely, due to the impediments previously detailed, that the nature of any potential horticultural system operating in lowland New Guinea in the late Holocene would have been distinctively transformed from that practised in the highlands. Endemic malaria would likely have constrained population growth and the logistical differences of lowland environments would have made their own impact. The highland 'agricultural' system would likely never have driven widespread population expansion.

Conversely, the dating of early Lapita sites suggests populations expanded into remote Oceania c.3250–3200 cal BP, within a hundred years of their first appearance in the Bismarck Archipelago (Specht, 2007, pp.55; Summerhayes, 2007, 2010, pp.24–25). This expansion, by a highly mobile, sea-faring and largely Austronesian population (Skoglund et al., 2016), saw a continued process of colonisation and interaction across Oceania; populations reaching Tonga c.2863–2835 cal BP and Samoa c.2800–2750 cal BP (Summerhayes, 2000; Summerhayes, 2010; Burley et al., 2015; Petchey, 2016).

The extent and timing of the expansion of this population is archaeologically visible. However, there is debate surrounding the subsistence strategies that allowed for the colonisation of remote Oceania. This is fueled in part, as in northern Sahul, by a scarcity of archaeobotanical evidence for the region (Anderson, 2008, pp.1505) and a reliance on the ethnohistoric record. In traditional, ethnographically-reliant interpretations Lapita populations have been considered 'full blown' agriculturalists, their transportable niche of root and tree crops, and domestic pigs, dogs and chickens allowing the colonisation of remote and, at times, relatively depauperate islands (Kirch, 1997; Spriggs, 1997; Jones and Spriggs, 2002). However, as the regional picture of early colonisation has developed, archaeological evidence has increasingly suggested this early period of occupation was based on a coastally-focused subsistence economy, including fish, shellfish and naïve avifauna, supplemented by the chicken, and in and to the west of Vanuatu by the pig (Groube, 1971; Kennett et al., 2006; Anderson, 2008). The presence of domestic plants within this economy is not well understood. Whilst some proxy evidence for horticultural practices (e.g. erosion, forest clearance) is suggestive of their commencement during early Lapita occupation (Gosden and Webb, 1994; Spriggs, 1997), the majority suggest this did not occur until the late or post-Lapita period (Stevenson and Dodson, 1995; Stevenson, 1999; Anderson, 2002; Lentfer and Green, 2004; Lentfer and Torrence, 2007). The coastal-focus of early settlements – populations not expanding into the interior of islands until c.1000 BP (Hunt, 1987; Sand, 1996) – has led Kennett et al. (2006, pp.281) to argue that initially "foraging for wild food was the most important [subsistence] strategy." Food production then increased in importance as anthropogenic activities diminished wild resources on each island. Whether cultivars were a part of early Lapita colonisation, their productivity marginal for several generations (Summerhayes, 2010, pp.33), or were incorporated into this subsistence strategy at a later date, this early Lapita occupation phase appears to not have been fueled by the ability to colonise remote islands via agriculture, but by the pull of abundant wild resources.

The later development of intensive horticultural adaptations in this region and the incredible feat of prehistoric expansion into the Pacific has had the effect, in hindsight, of making agriculture appear inevitable. Similarly, it is the colonial conquest by European nations that supported the initial framework of cultural evolution constructed by nineteenth century social theorists. Perceiving the dominance of the Western World and considering its origins to be in agriculture, these scholars surmised that the adoption of agriculture must be a predestined step on the ladder of progress. However, the employment of the framework of niche construction to consider the subsistence practices of northern Sahul and Oceania, suggests that paths to domestication and other subsistence specialisations were varied and often inadvertent: an outcome of the interaction between subsistence practices and the inhabited environment. Indeed, the production or adoption of an active niche construction practice and/or a domesticated plant or animal is in each case socially and ecologically unique. Any seeming inevitability is, instead, a product of the expansion of historically unstable agricultural niches; pulled by the lure of new resources and pushed by population expansion and unsustainable practices.

5.2. Cultural contact and interaction revised

After c.3000 BP, populations in lowland New Guinea, possibly through cultural, as well as demic diffusion, came into contact with Lapita populations and their subsistence practices (McNiven et al., 2011; Gaffney et al., 2015). Whilst archaeological evidence for this contact and its effect on lowland subsistence systems is relatively scarce, the practices evident in the ethnohistoric record and the genetic evidence support the introduction of several domestic animals during this interaction. The dating of the only unambiguous evidence for horticultural subsistence in the northern Torres Strait, and indeed lowland New Guinea, to 780 ± 70 BP, may suggest that horticultural practices were introduced to the southern lowlands during ongoing interaction with other Melanesian and Austronesian populations in the late Holocene (Harris, 1995). Whether this is the case, this date leaves a spatially and temporally narrow window, through which the Indigenous populations of northern Australia might have adopted the cultigens and horticultural practices of the Torres Strait.

It is, therefore, clear that the economic, cultural and environmental barriers to agricultural expansion initially posed by White (1971) are no longer necessary to explain the subsistence practices of the Indigenous populations of northern Australia. Indeed, archaeological evidence for northern Australia suggests that these populations were not closed to the adoption of foreign subsistence practices. This includes the introduction of the dingo to Australia by 3500 BP (Milham and Thompson, 1976; Savolainen et al., 2004; Oskarsson et al., 2012) and the introduction of Macassan technology (steel), and the practice of dugong hunting to the Coburg Peninsula, northern Australia, in the late Holocene (Mitchell, 1994b, 1994a). The former affected change in subsistence practices across the Australian mainland. Preliminary data suggests Indigenous Australian hunting patterns adapted to include the dingo as a hunting partner (Balme and O'Connor, 2016). The latter illuminates the nature of contact between northern Australians and sea-faring 'agriculturalists'; the Macassan trading population offering marine, rather than agrarian, subsistence specialisations. Indigenous Australian populations have a dynamic pre-colonial history of

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active niche construction and when possible have been shown to be both innovative and open to new technology. Neither their affluence nor their purported development of elaborate and restrictive religious constructs acted as a prohibitive barrier.

Therefore, in order to properly consider contact between different subsistence systems in Sahul, it seems necessary to shift the focus of research from the northern Australian/Torres Strait divide. One of the more fruitful regions for this analysis may, instead, be in lowland New Guinea and the Bismarck Archipelago where different cultural and ethnic groups, involved in different endemic subsistence practices, interacted in the late Holocene (see Lilley, 2000). Tantalising genetic, linguistic and ethnographic evidence for this region suggests the variable admixture of genes, languages and subsistence practices (Hagelberg et al., 1999). Indeed, the hypothesised process of assimilation of horticultural practices, left the lowlands with a patchwork of economic systems and communities, reliant to different degrees on domesticated plants and animals (Powell, 1976; Allen, 1977; Sillitoe, 2002). This apparent process of agricultural adoption is in line with what niche construction might predict for this region. Subsistence systems are not defined as either/or, but instead include a varied array of subsistence practices; each subsistence system a product of local environment, past subsistence practices, and the process of interaction and adoption.

6. Conclusion

The 'Neolithic problem' is a product of both over-reliance on the ethnographic record and the anachronistic theoretical lens through which it has been viewed. There is neither an inherent aversion in the Indigenous populations of northern Australia to the adoption of outside practices, nor an extensive and prolonged agricultural frontier in the Torres Strait across which these practices were resisted. Indeed, the centre of contact in this region may instead be found in the lowlands of New Guinea and the Bismarck Archipelago. It is, therefore, time that researchers move past both the 'Neolithic problem' and the search for an either/or concept of agriculture in northern Sahul from which it has developed.

For this to be achieved, two things must occur. First, the archaeological and ethnohistoric record of Sahul must be re-examined through a theoretical framework, which, as White (2011, pp.90) wrote, rejects "the hierarchical ordering of groups into hunter-gatherers, small-scale food producers and agriculturalists." Second, the ethnohistoric record must only be considered representative of the recent past. We have taken the first steps to realise this, using niche construction theory to allow for the re-examination of subsistence systems across northern Sahul without the structural baggage of the nineteenth century concept of cultural evolution.

The investigation of the archaeological record through the framework of niche construction theory has allowed both for the observation of different practices of active niche construction and for the comprehension of the development of such practices as a process of interaction between local environments and populations. This has delivered two outcomes. First, practices of landscape modification (e.g. vegetation burning, water management and the introduction of new biota) have been viewed as practices that increase the yield of a given environment in the same sense as small-scale plant cultivation and animal husbandry. Second, that subsistence systems have been examined as environmentally-, culturally- and historically-specific products, allowing for a more thorough understanding of their development, expansion and interaction.

As Fairbairn (2005) and Denham et al. (2009a; 2009c) have already argued, however, this is only one of the components necessary for continued progress into the examination of subsistence systems within northern Sahul. It is also imperative that researchers implement the multi-proxy, archaeobotanically-focused studies often missing in the lowlands of New Guinea and Australia. These investigations need to consider subsistence practices on both a site and landscape scale; multiple excavations allowing comparison across a region. They also need to integrate multiple lines of archaeological, palaeoenvironmental and genetic evidence, allowing for the effects of anthropogenic actions and environmental changes to be disentangled. In the field of archaeobotany, this means that the systematic recovery of macro- and micro-botanical remains must be a standard practice in archaeological research strategies and further research must be conducted into the identification and quantification of tropical plant foods (Fairbairn, 2005).

Whilst further archaeological investigation is required to understand the nuances of pre-colonial contact in northern Sahul, it is clear that the interactions between populations in this region are much more complex than that represented in earlier ethnographic anecdotes. Further, the image of culturally-static and homogenous Indigenous Australian populations often implied in the consideration of forager/farmer interactions further afield, is not supported by the archaeological or the ethnographic evidence for this region and, therefore, belongs to another era of archaeological thought.

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